examined as a function of NTSC CCIR impairment, location and distance.

Margin was calculated by first measuring the ATV signal-to-noise (S/N) as received, then adding white Gaussian noise in 1 dB increments until the threshold of errors exceeding a value of 3×10^{-6} was reached, and remeasuring the S/N. The difference between the two values is the margin. Each BER measurement takes one minute to record, or a total of two minutes for a complete sequence. The S/N recorded is believed to be recorded for the "worst case" signal fade during this two minute interval.

2.1 ATV Margin versus CCIR Impairment Rating

To determine the ATV margin statistics corresponding to the various CCIR impairment ratings obtained from the NTSC service availability analysis, measurements at locations where ATV reception was satisfactory (BER $< 3 \times 10^{-6}$) were grouped according to their corresponding NTSC CCIR impairment ratings at the same locations. Then, the median ATV margin and standard deviation were determined for each rating. Tables 10 and 11 present the margin statistics for channels 6 and 53. (Channel 53 margin standard deviation for CCIR rating 1 is considered unreliable because of the small sample size (n = 5).)

TABLE 10

ATV Margin Statistics versus CCIR Impairment Rating*

(Channel 6)

CCIR IMPAIRMENT SCALE	N[illegible] of M[illegible]ed	% of ATV Sites BER $< 3 \times 10^{-6}$	ATV Margin (dB)	
			Median	Std. Dev.
5 Imperceptible	4	100	43.7	4.51
4 Perceptible, but not Annoying	22	100	38.2	7.40
3 Slightly Annoying	41	100	25.6	9.73
2 Annoying	46	93	16.9	7.23
1 Very Annoying	56	50	15.0	8.0

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

TABLE 11

ATV Margin Statistics versus CCIR Impairment Rating*

(Channel 53)

CCIR IMPAIRMENT SCALE	Number of Sites Measured	% of ATV Sites BER < 3 x10^{-6}	ATV Margin (dB)	
			Median	Std. Dev.
5 Imperceptible	7	100	41.2	8.26
4 Perceptible, but not Annoying	104	100	32.4	9.77
3 Slightly Annoying	41	98	19.9	11.06
2 Annoying	29	90	7.7	7.7
1 Very Annoying	18	28	19.7	14.13

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

The ATV margin statistics in Tables 10 and 11 show that, where the NTSC signal has a CCIR impairment rating of 3, the median ATV margin is 25.6 dB with standard deviation of 9.73 for channel 6, and margin and standard deviation for channel 53 of 19.9 dB and 11.06 dB, respectively. These values provide ample ATV margin for locations where NTSC has CCIR rating 3.

2.2 ATV Margin Statistics for Grid Measurements

Tables 12 and 13 show the median ATV margin and standard deviations for channel 6 and 53 for both the Charlotte and Rock Hill grid measurements where ATV BER was less than 3 x10^{-6}. (Channel 6 Rock Hill grid standard deviation is considered unreliable because of the small sample size (n = 8).)

TABLE 12

ATV Margin Statistics for Grid and Cluster Measurements*

(Channel 6)

GRID & CLUSTER LOCATION	Number of Sites Measured	% of ATV Sites BER < 3 x10^{-6}	ATV Margin (dB)	
			Median	Std. Dev.
Charlotte (G1/C1)	33	97	30.4	10.24
Rock Hill (G2/C2)	9	89	19.6	5.17

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

TABLE 13

ATV Margin Statistics for Grid and Cluster Measurements*

(Channel 53)

GRID & CLUSTER LOCATION	Number of Sites Measured	% of ATV sites BER < 3 x10^{-6}	ATV Margin (dB)	
			Median	Std. Dev.
Charlotte (G1/C1)	33	94	39.6	9.96
Rock Hill (G2/C2)	33	94	25.1	10.16

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

Tables 12 and 13 show that a sufficient margin exists for both the urban and suburban grids to deal with changes in signal levels within the grid. The data also show that the median margin value for channel 53 is greater than for channel 6. This finding is somewhat unexpected, and could be attributed to the prevalence of impulse noise and/or the presence of low level interference from cable on channel 6 within the grid. Furthermore, the small difference in standard deviation values between channels 6 and 53 in the Charlotte grid, suggests these margin variations from location-to-location (i.e., location variability) are similar for VHF and UHF. This is somewhat contrary to previous findings on location variability [Reference 1, 2]. One possible explanation for this anomaly is the prevalence of impulse noise within the grid. No comparison with the Rock Hill grid is possible because of the small sample size for channel 6. In addition, the standard deviations for both grids on channel 53 are similar. This result is consistent with findings on location variability. [Reference 2].

2.3 ATV Margin Statistics versus Distance

Tables 14 and 15 present ATV margin statistics versus distance for channels 6 and 53. The statistics include grids, cluster and radial measurements where ATV BER was less than 3 x10^{-6}. Because of the small sample size, the standard deviations for channel 6 and 53 for distances greater than 50 miles are considered unreliable.

TABLE 14

ATV Margin Statistics versus Distance*

(Channel 6)

DISTANCE (miles)	Number of Sites Measured	% of ATV Sites BER < 3 x10^{-6}	ATV Margin (dB)	
			Median	Std. Dev.
0 - 9.9	27	96	30.8	10.81
10.0 - 19.9	38	97	31.6	10.61
20.0 - 29.9	33	94	21.1	7.58
30.0 - 39.9	28	89	14.0	6.99
40.0 - 49.9	28	57	13.9	6.87
50.0 - 56.0	15	20	14.1	6.65

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

TABLE 15

ATV Margin Statistics versus Distance*

(Channel 53)

DISTANCE (miles)	Number of Sites Measured	% of ATV Sites BER < 3 x10^{-6}	ATV Margin (dB)	
			Median	Std. Dev.
0 - 9.9	32	97	40.8	10.08
10.0 - 19.9	38	97	34.0	8.15
20.0 - 29.9	51	98	25.0	8.67
30.0 - 39.9		91	15.4	9.95
40.0 - 49.9	28	86	18.0	9.28
50.0 - 56.0	16	56	10.7	8.40

* NTSC peak power was 10 dB below maximum allowable power
The ATV average power level was 12 dB below NTSC peak power.

The data in tables 14 and 15 show that except for distances over 50 miles, the ATV margin median values for channel 53 are greater than for channel 6. For distance greater than 20 miles the standard deviation averaged around 7 dB for channel 6 and around 9 dB for channel 53. The data also show a good margin for all distance groupings.

3. Equalizer Tap Energy

To evaluate the performance of the ATV system under different multipath conditions, a number of parameters, such as equalizer signal-to-noise ratio at the input and output of the equalizer, and equalizer tap energy, were recorded. The tap energy is not only a good parameter to assess how hard the equalizer is working, but a reliable indicator of how severe and complex the multipath or time varying conditions are for a given location or area. Presented below is an assessment of the equalizer performance.

3.1 Equalizer Tap Energy Statistics

Table 16 presents tap energy statistics for all measurement locations where BER was less than 3 $\times 10^{-6}$ for channels 6 and 53. Tap Energy is defined as the ratio of the energy in all of the equalizer taps other than the main tap to that of the main tap. The higher the tap energy, the harder the equalizer works to overcome multipath conditions. Also, the higher the tap energy, the more severe the multipath conditions are. Figures 4 and 5 are frequency distribution plots of the tap energy versus number of locations for channels 6 and 53. The data is grouped in 2 dB steps.

TABLE 16

ATV Tap Energy Statistics for all Measurement Locations above Threshold

(Channel 6 & 53)

ATV Tap Energy	Ch. 6	Ch. 53
Sample size	138	182
Median (dB)	-18.3	-18.1
Standard Deviation (dB)	2.86	3.83
Minimum level (dB)	-22.4	-25.7
Maximum Level (dB)	-7.7	-4.7

The data in table 16 show that the median values are approximately the same for channels 6 and 53. The standard deviation, however, is larger for channel 53 than for channel 6. This is to be expected since multipath conditions are more prevalent in UHF than VHF. The data also show that the multipath conditions in the Charlotte area are well within the performance range of the equalizer.

3.2 Equalizer Tap Energy Statistics for Grid Measurements

Tables 17 and 18 present the median ATV tap-energy and standard deviation for channels 6 and 53 for both the Charlotte and Rock Hill grid measurement locations where the BER was less than 3×10^{-6}. Channel 6 Rock Hill standard deviation is considered unreliable because of the small sample size.

TABLE 17

ATV Tap Energy Statistics for Grid Measurements

(Channel 6)

GRID & CLUSTER LOCATIONS	ATV Sites BER < 3×10^{-6}	ATV Tap Energy (dB)	
		Median	Std. Dev.
Charlotte (G1/C1)	32	-15.6	4.66
Rock Hill (G2/C2)	8	-17.6	5.18

TABLE 18

ATV Tap Energy Statistics for Grid Measurements

(Channel 53)

GRID & CLUSTER LOCATIONS	ATV Sites BER < 3×10^{-6}	ATV Tap Energy (dB)	
		Median	Std. Dev.
Charlotte (G1/C1)	31	-17.6	4.95
Rock Hill (G2/C2)	31	-14.8	3.54

The data in tables 17 and 18 show that for the median value for the Charlotte grid (urban) is lower for channel 53 than for channel 6. The data also show that the median value for channel 53 Rock Hill grid is higher than for the Charlotte grid The data indicate that the multipath conditions encountered in the suburban (Rock Hill) grid were more severe than for the urban (Charlotte) grid.

3.3 Equalizer Tap Energy versus Distance

Tables 19 and 20 present tap energy statistics versus distance for channels 6 and 53. The statistics include both grids and radial measurement locations where the ATV BER was less than 3 $\times 10^{-6}$. Because of the small sample size, the standard deviations for channels 6 and 53 for distances greater than 50 miles are considered unreliable.

TABLE 19

ATV Tap Energy Statistics versus Distance

(Channel 6)

DISTANCE (miles)	ATV Sites BER < 3 $\times 10^{-6}$	**ATV Tap Energy (dB)**	
		Median	Std. Dev.
0 - 9.9	26	-17.0	4.67
10.0 - 19.9	37	-18.5	3.22
20.0 - 29.9	31	-18.5	3.32
30.0 - 39.9	25	-18.5	1.56
40.0 - 49.9	16	-19.1	3.01
50.0 - 56.0	3	-19.3	2.15

TABLE 20

ATV Tap Energy Statistics versus Distance

(Channel 53)

DISTANCE (miles)	ATV Sites BER < 3 x10^{-6}	ATV Tap Energy (dB)	
		Median	Std. Dev.
0 - 9.9	31	-18.0	4.75
10.0 - 19.9	37	-18.45	3.72
20.0 - 29.9	50	-18.5	4.21
30.0 - 39.9	31	-16.3	3.23
40.0 - 49.9	24	-18.8	4.66
50.0 - 56.0	9	-18.9	2.19

The data in tables 19 and 20 show that while the median values for the various distance groupings are similar the standard deviations for channel 53 are generally higher than for channel 6. This finding is consistent with the earlier finding that multipath conditions are more prevalent in UHF than in VHF.

4. Noise Floor Measurements

Table 21 presents noise floor statistics for all 169 measurement locations for channel 6 and all 199 locations for channel 53. Figure 6 is the frequency distribution plot of the noise floor levels in dBm versus number of locations for channel 6. Data were grouped in 1 dB steps. No plot was included for channel 53 since most of the data were within 2 dB of the median.

TABLE 21

ATV Noise floor statistics for all Measurement Locations

(Channel 6 & 53)

ATV Noise Floor	Ch. 6	Ch. 53
Sample size	169	199
Median (dBm)	-63.2	-70.7
Standard Deviation (dB)	7.04	1.68
Minimum level (dBm)	-74.3	-71.9
Maximum Level (dBm)	-45.8	-58.1

The data in table 21 show the median noise floor level and standard deviation for channel 6 were significantly higher than for channel 53. The elevated noise for channel 6 is believed to be attributable to one or more of these following factors: the prevalence of impulse noise which was present in at least 46 percent of the measured sites; the presence of cochannel interference from distant stations; the presence of low level interference from cable installations; and interference from close-by noncommercial educational FM stations.

5. C/N Ratio at BER Threshold

Table 22 presents C/N ratio statistics for all measurement locations where ATV BER was less than the threshold. Taking into account the accuracy of the field measurement equipment, the median values are consistent with the data measured at ATTC The minimum level reported below for channel 6 is caused by the presence of a strong co-channel interferer. Under cochannel interference conditions the 8-VSB system is capable of operating at the desired-to-undesired ratio of as low as 2 dB, as determined by using the "rotating pyramids" an NTSC interferer at ATTC.

TABLE 22

ATV C/N Ratio (at BER Threshold) Statistics for all Measurement Locations*

(Channel 6 & 53)

ATV C/N Ratio	**Ch. 6**	**Ch. 53**
Sample size	138	182
Median (dB)	14.9	15.6
Standard Deviation (dB)	[illegible].39	2.67
Minimum level (dB)	3.8	14.3
Maximum Level (dB)	18.8	24.8

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

6. Presence of Cochannel NTSC Signal

Cochannel signal levels of measurable magnitude were recorded on 95% of the locations on channel 6 and only 15% of the locations on channel 53. Table 23 presents the distribution of ATV/NTSC cochannel Desired-to-Undesired (D/U) ratio for channel 6. No table was included for channel 53 because of a limited number of locations where cochannel interference was present.

TABLE 23

Distribution of ATV/NTSC co-channel D/U Ratio*

(Channel 6)

ATV/NTSC DESIRED/UNDESIRED RATIO (dB)	Percent of Sites
-5 - 0	1
0 - 9.9	5
10.0 - 19.9	19
20.0 - 29.9	35
30.0 - 39.9	26
40.0 - 49.9	9
50.0 or Greater	5

* NTSC peak power was 10 dB below maximum allowable power.
The ATV average power level was 12 dB below NTSC peak power.

Table 23 shows that approximately 25% of the ATV locations measured D/U ratios of less than 20 dB -- ratios strong enough to cause interference if the desired station was another NTSC station. Given the above statistics, one can conclude that the ATV system performed well in the presence of a cochannel signal. Also, note that the prevalence of NTSC cochannel signals throughout the entire service area suggests that these signals did not only originate from distant stations but from cable installations within the Charlotte area.

IV. SUPPLEMENTARY TESTS

In addition to the basic tests reported above, three supplementary tests were performed. These included: co-channel interference, reception on indoor antennas and reception from a UHF directional transmitting antenna. The procedures employed and results obtained are described below.

A. Cochannel Interference

Desired-to-undesired (D/U) co-channel interference ratios were determined by making use of a translator located approximately 27 miles from the Charlotte test transmitter on a bearing of approximately 29 degrees. The tests were performed on UHF channel 53. Since both the main transmitter and the translator could be operated in either NTSC or ATV mode, tests could be made, and were made, for all three interference combinations: ATV to NTSC, NTSC to ATV, and ATV to ATV. By adjusting the powers of the main and interfering signals, the point where interference could be barely detected in an NTSC display, or where a BER threshold of $3x10^{-6}$ is encountered can be determined.

In the ATV to NTSC tests, D/U ratios of 49, 50.1 and 50.3 dB were found, respectively, at the three locations where measurements were made. This ratio compares to 48.54 dB measured at ATTC. At four locations where NTSC to ATV was measured, the D/U at TOV ratios were 1.0, 0.2, 4.3, and 5.0 respectively, compared to the 2.07 dB ratio measured at ATTC. For ATV to ATV, at the four locations where measurements were made, the D/U ratios were 14.7, 14.2, 16.4, and 17.8 dB, respectively, compared to 15.91 dB measured at ATTC. Laboratory determinations of D/U ratios, where test conditions can be controlled, are preferable to field determinations for the development of planning factors. The field results herein support the validity of the laboratory measurements.

B. Reception on Indoor Antennas

In relatively strong signal areas, in locations where an outdoor antenna cannot be employed, or perhaps for receivers other than the principal receiver in the home, many householders rely on set-mounted indoor antennas for NTSC reception. To test whether, in those instances, ATV reception is feasible, indoor reception of channel 53 was observed at 12 locations ranging in distance from 4.6 miles to 24.1 miles from the Charlotte transmitter site. These were locations where permission could be obtained to enter homes and make the necessary measurements and observations. For comparison purposes, outdoor measurements were made also at locations as close as feasible to the homes. The outdoor measurements were made using the same equipment and techniques as employed for the basic tests made at the 199 radial and grid sites.

Satisfactory reception with adequate ATV margin was obtained at all twelve locations. NTSC reception at two of the residences was rated at less than the threshold impairment rating of three without ghost cancellation, the ratings increased to three at both places when the ghost canceling circuit was switched in. Only one residence showed an ATV margin of less than 10 dB. That low value was 7.8 dB. Other margins at the twelve indoor locations ranged from 10.5 to 33.5. At nearby locations outdoors, ATV margins ranged from 33.1 to 56.3 dB

C. Reception from a UHF Directional Transmitting Antenna

The antenna employed for the basic tests is top mounte and omnidirectional. Considering that some broadcasters are likely to choose to side mount antennas and use directivity to concentrate service in particular directions, tests were made on a UHF antenna side mounted below both the channel 6 and channel 53 top mounted antennas. Maximum NTSC peak visual ERP for the directional antenna was 500 kW, 10 dB below the maximum permitted, and maximum ATV average ERP was 12 dB below the NTSC peak visual ERP Measurements were made at 13 locations approximately 16 miles from the transmitting antenna, of which eight were in the "back side" of the radiation pattern and the remaining five locations were in the m eam. The antenna radiation characteristics, a map showing orientation, and a map showing the locations of the measuring points are included in Appendix 4

At two sites, in the most suppressed parts of the directional pattern, neither NTSC nor ATV produced useable signals. At one of those two sites, the ATV bit error rate and segment error rate were zero, but the margin was unacceptably low, indicating that the picture would be intermittent. If the main beam maximum peak visual NTSC ERP had been near the maximum permitted, and ATV ERP had been 12 dB below that level, the expectation is that both NTSC and ATV would have produced satisfactory reception.

V. SUMMARY OF FINDINGS

A. Service Availability Performan

For the entire sample of 169 for VHF and 199 for UHF, satisfactory VHF NTSC reception was found at only 39.6 percent of the locations compared to 81.7 percent for ATV reception.

Satisfactory UHF NTSC reception was found at 76.3 percent of the locations compared to 91.5 percent for ATV. The relatively poor performance of the VHF signals relative to UHF is believed to be attributable to the prevalence of impulse noise within the service area, interference from co-channel stations, the presence of low level interference from cable use of channel 6, and/or interference to channel 6 reception from close-by noncommercial educational FM stations.

ATV performance was better than NTSC performance at all distance groupings from the transmitter. For the entire range of distances, and for all sites where observations and measurements were made, 82 percent of the locations demonstrated satisfactory ATV results on channel 6 contrasted with 40 percent for NTSC. On channel 53, 91 percent of the sites showed that ATV reception would be satisfactory compared to 75 percent for NTSC. At the outermost portions of the service area, beyond 50 miles, 3 of the total 15 sites demonstrated satisfactory reception for ATV on Channel 6, but none of the 15 NTSC sites had NTSC service with a CCIR impairment rating of 3 or better. For the same points beyond 50 miles, 9 of the 16 sites had satisfactory UHF ATV reception compared to only 4 of the 16 sites having satisfactory NTSC reception.

B. <u>ATV System Performance</u>

The ATV system performed well under real world conditions of multipath and other propagation phenomena, impulse noise and cochannel interference. The system provided ample ATV margin -- a median ATV margin of 25.6 dB for channel 6 and 19.9 dB for channel 53 -- for locations where NTSC CCIR rating 3, and to deal with changes in signal levels from location to location. The conditions encountered in Charlotte were well within the performance range of the equalizer. The ATV system also performed well in the presence of strong cochannel NTSC signal. The ATV system performed significantly better than NTSC in the presence of impulse noise. Further investigation into the cause and effect of impulse noise on both NTSC and ATV in the Charlotte area is warranted.

All in all, the over-the-air system performance for ATV was better than NTSC.

VI. ACKNOWLEDGMENTS

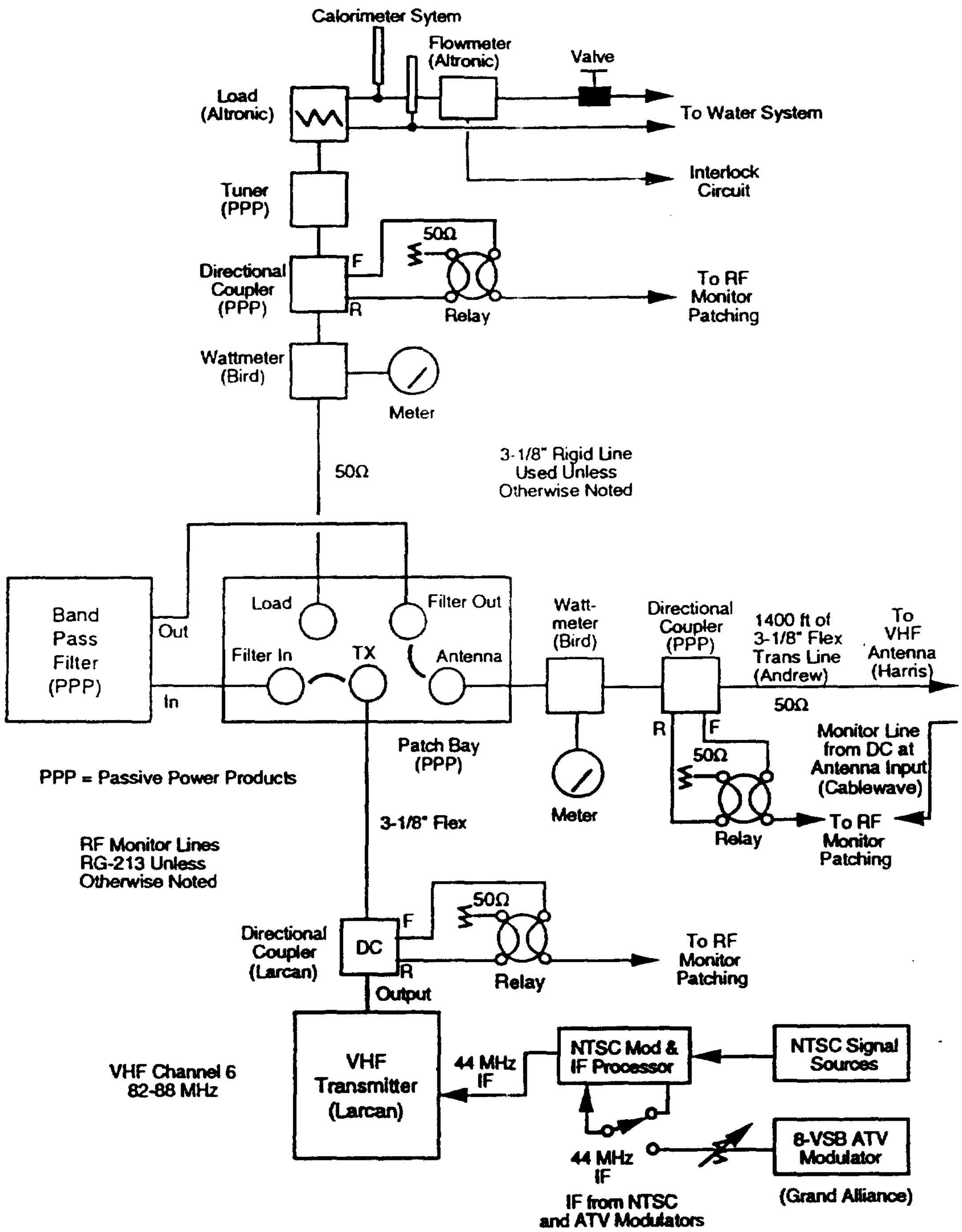
The field testing project was well served by many dedicated persons. Especially to be acknowledged for their contributions are: Edmund Williams, Project Manager, Lanny Nass, Field Truck Supervisor, Peter Kok, Field Truck Operator, Peyton Hines, Transmitter Supervisor, and Zenith engineers Richard Citta, Robert Densler, Steven Heinz, Leif Otto and Gary Sgrignoli.

REFERENCES

[1] VHF and UHF propagation curves for the range 30 to 1000 MHz - Broadcasting Services. CCIR Recommendation 370-5 and Report 239, Vol. 5, XVIth Plenary Assembly, Dubrovnick 1986.

[2] Longley A. G., "location Variability of Transmission Loss -- Land Mobile and Broadcast Systems," OT Report 76-87, May 1976.

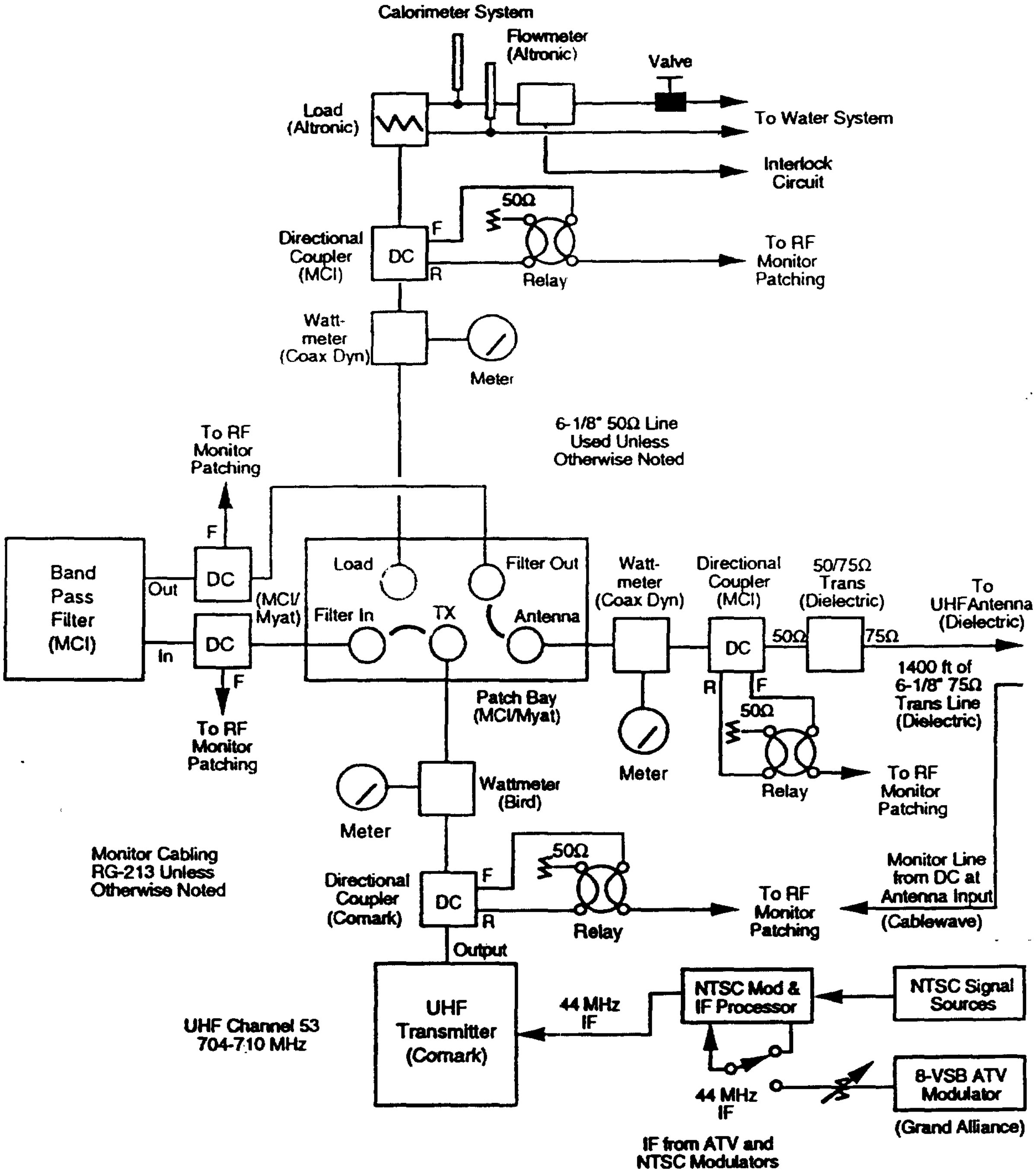
FIGURES



VHF RF Transmission System

ATV Field Test Project
Charlotte, North Carolina

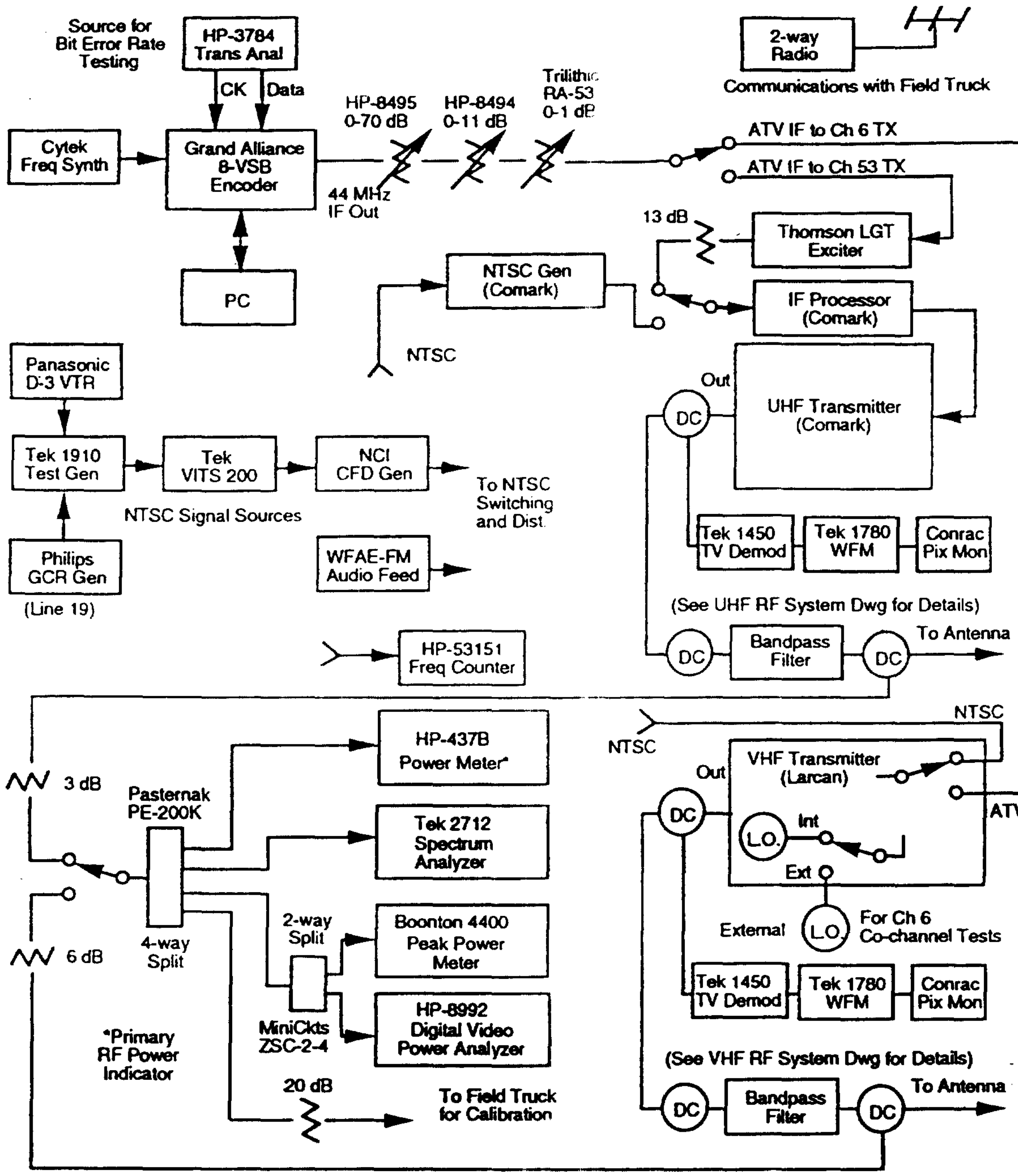
3/94



UHF RF Transmission System

ATV Field Test Project
Charlotte, North Carolina

3/94

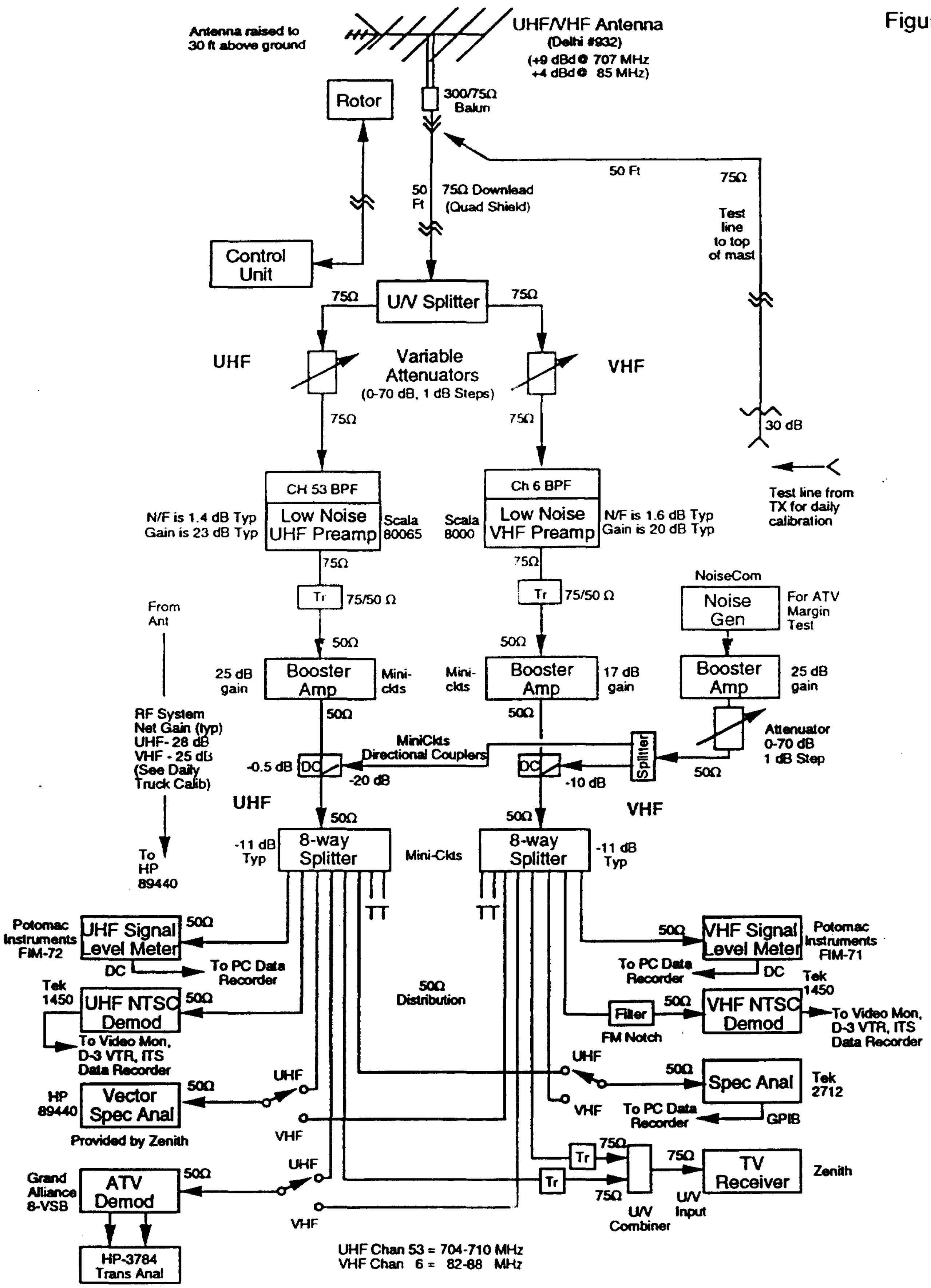


Signal Sources & RF Power Monitoring

ATV Field Test Project
Charlotte, North Carolina

3/94

Figure 2



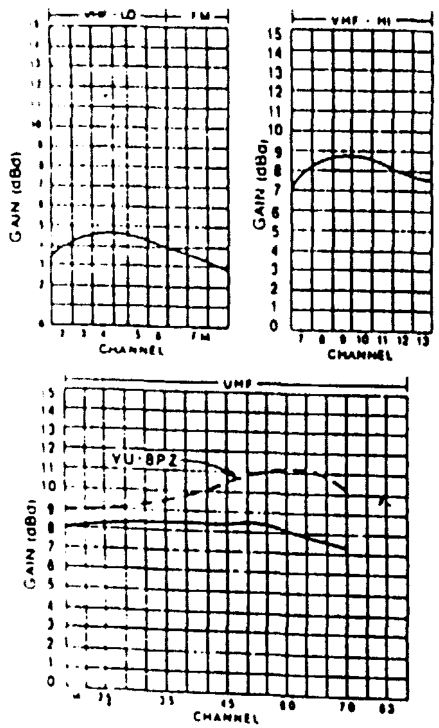
Field Truck RF Distribution System

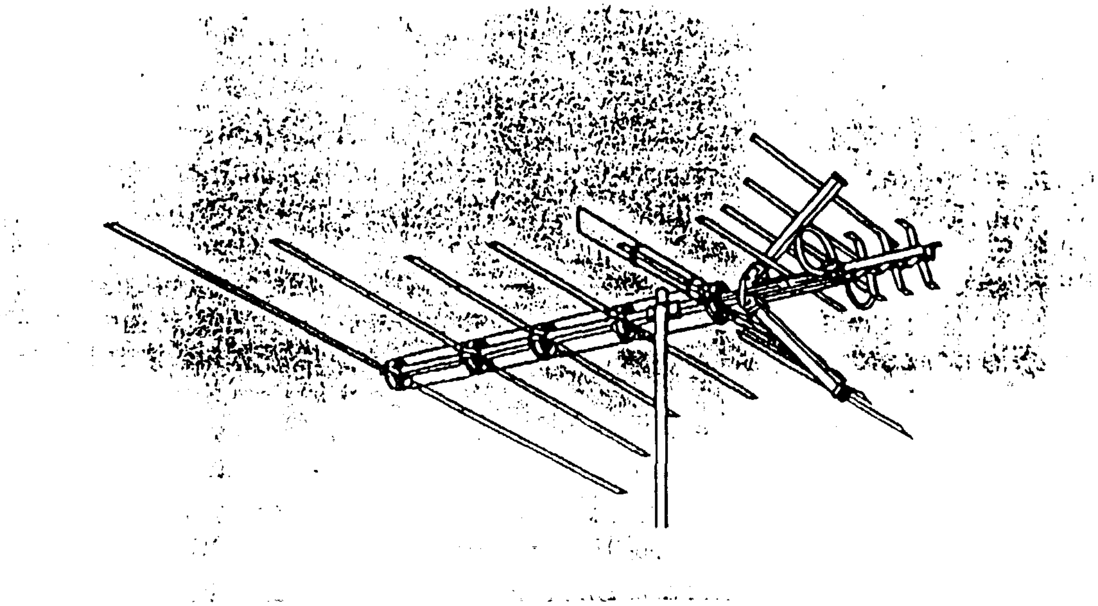
ATV Field Test Project
Charlotte, North Carolina

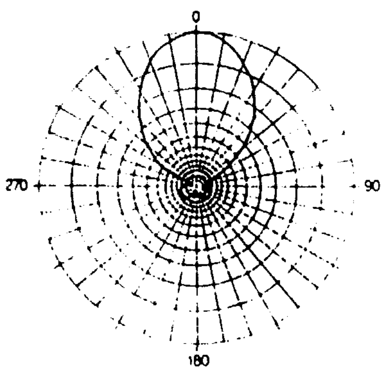
5/10/94

All Channel
Model VU-932SR

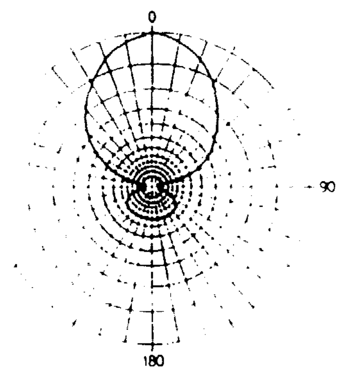
Range - metropolitan
Elements - 24
Length - 5'8½" (1.74 m)
Weight - 8 lbs. (3.62 kg)



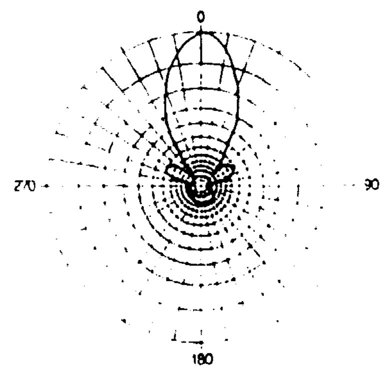




UHF



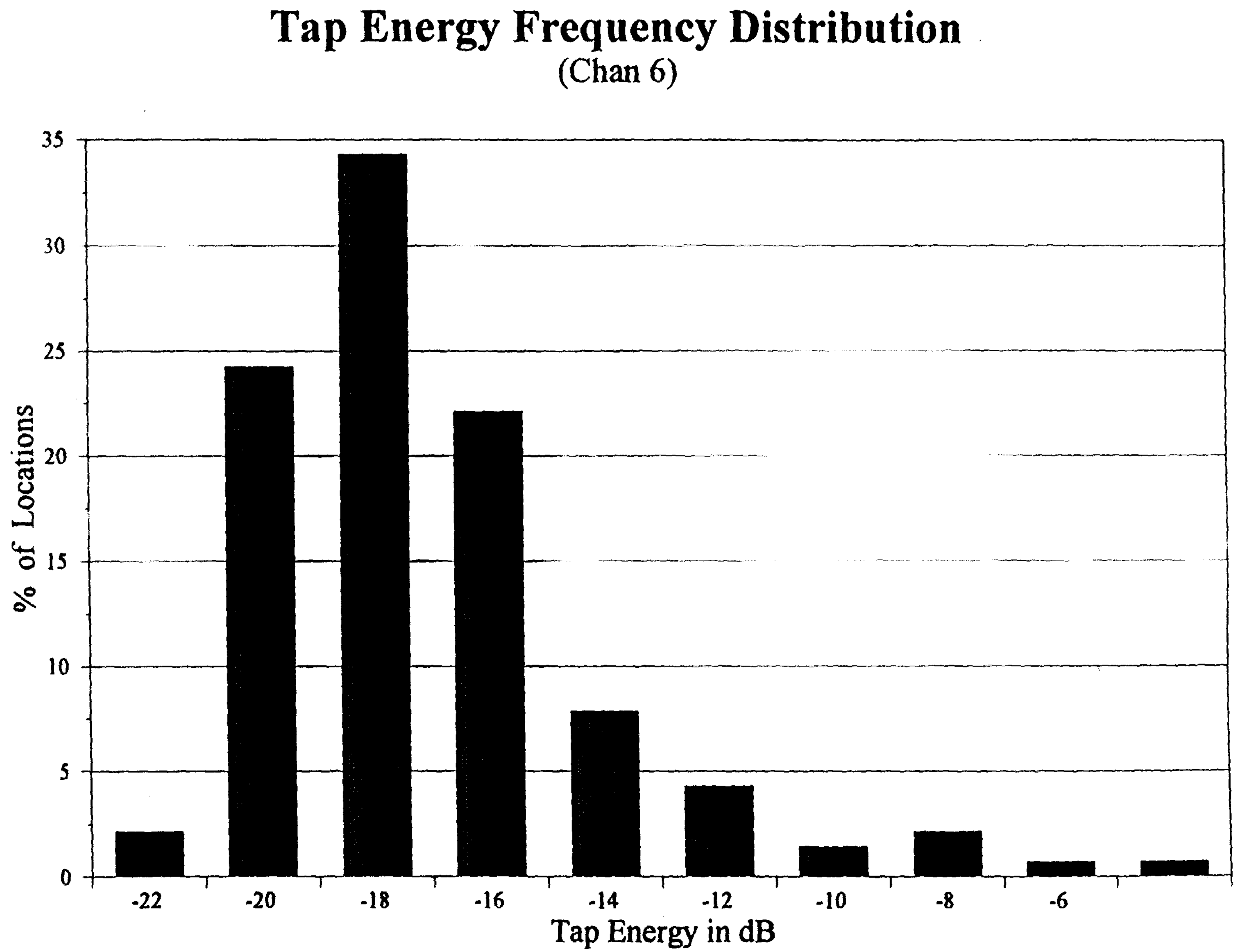
LO-VHF



HI-VHF

Cometic Technology Inc., 65 Waverly Street, Delhi, Ontario, Canada N4B 1E8

Figure 3



Tap Energy Frequency Distribution
(Chan 6)
35
30
25
20
15
10
5
0
% of Locations
-22
-20
-18
-16
-14
-12
-10
-8
-6
Tap Energy in dB

figure 4

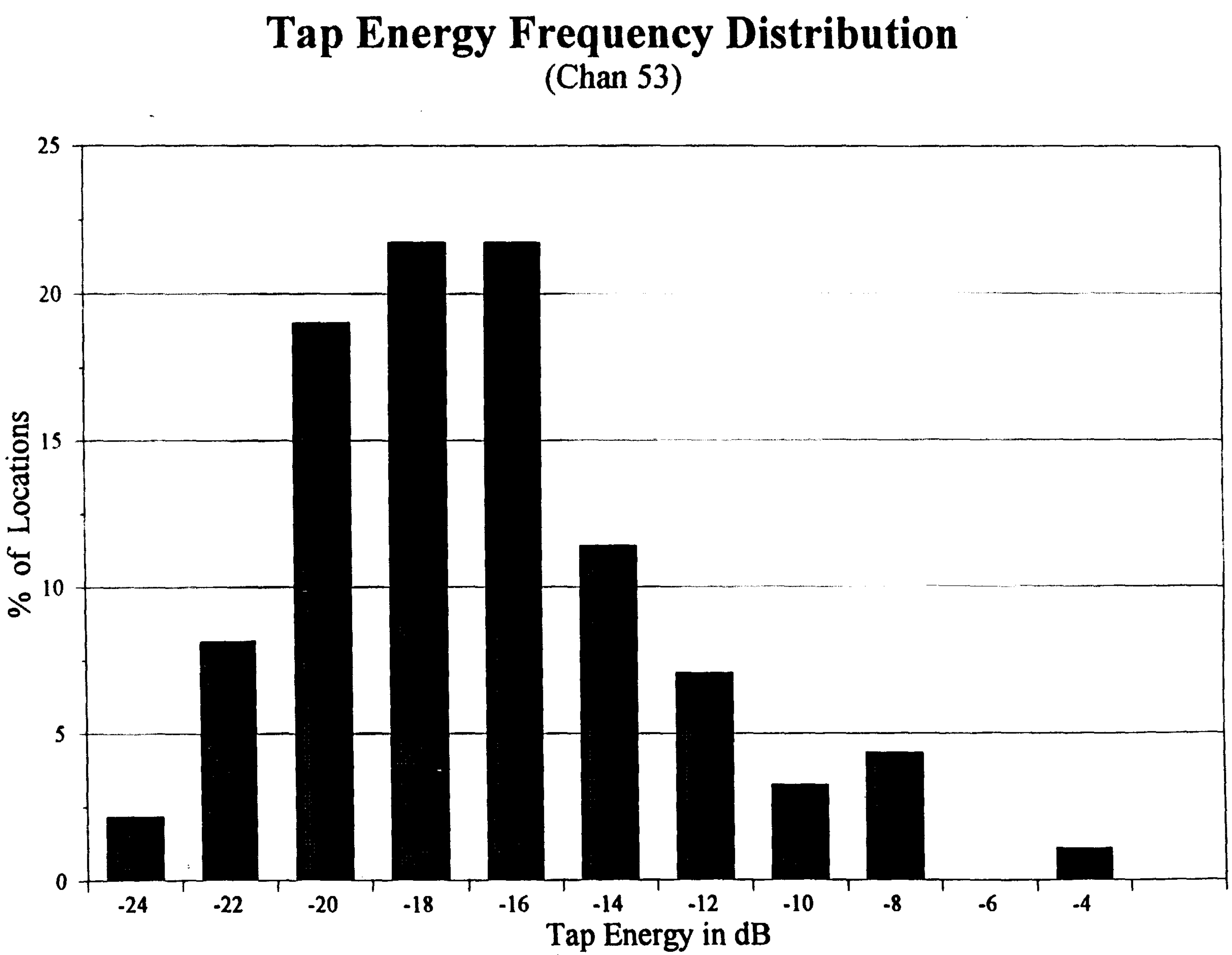

Tap Energy Frequency Distribution
(Chan 53)
25
20
15
10
5
0
% of Locations
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
Tap Energy in dB

figure 5

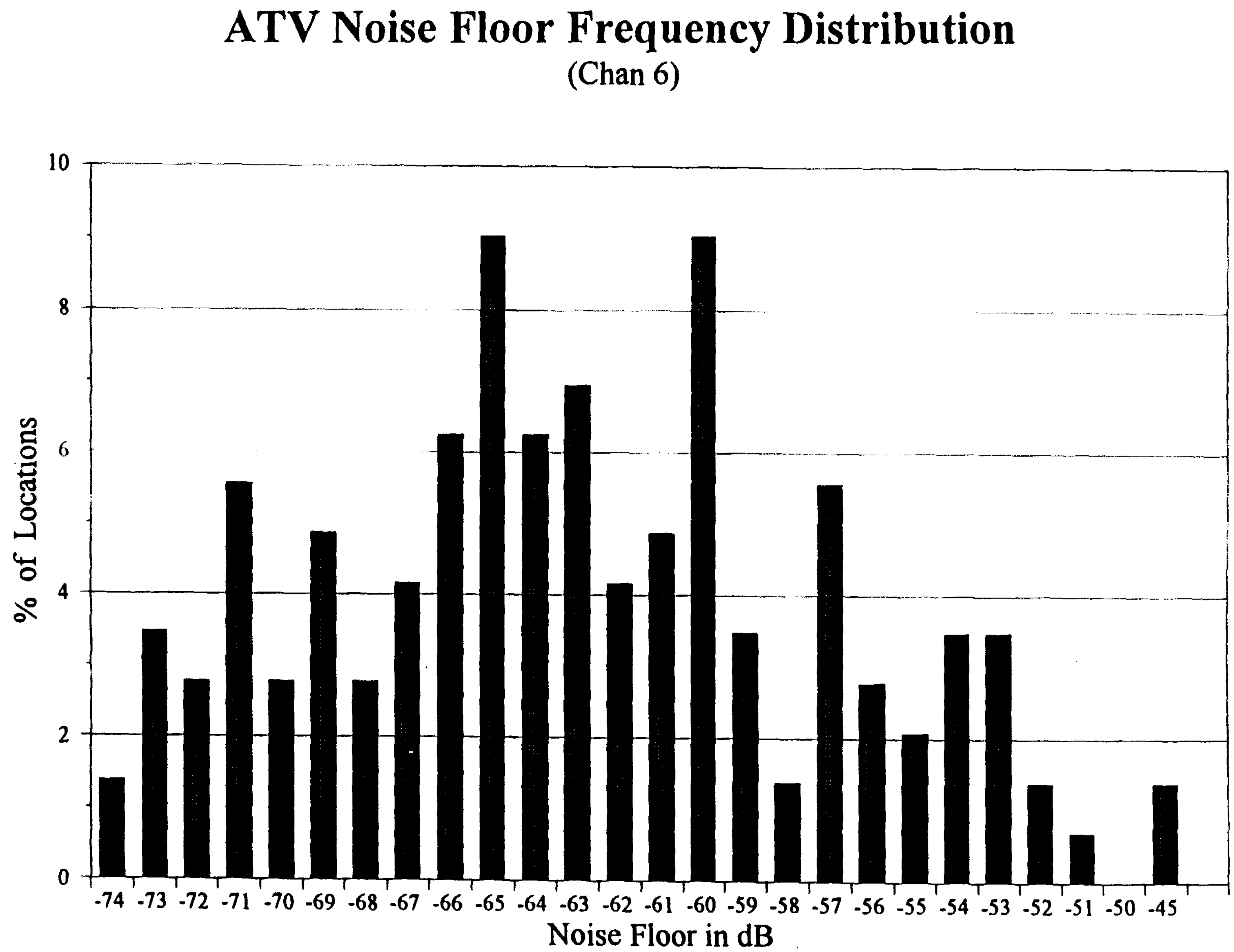

ATV Noise Floor Frequency Distribution
(Chan 6)
10
8
6
4
2
0
% of Locations
-74 -73 -72 -71 -70 -69 -68 -67 -66 -65 -64 -63 -62 -61 -60 -59 -58 -57 -56 -55 -54 -53 -52 -51 -50 -45
Noise Floor in dB

figure 6